

CHARACTERISTICS OF IMPACT CRATERS AND INTERIOR DEPOSITS: ANALYSIS OF THE SPATIAL AND TEMPORAL DISTRIBUTION OF VOLATILES IN THE HIGHLANDS OF MARS. S.C. Mest, Planetary Geodynamics Laboratory (Code 698), NASA Goddard Space Flight Center, Bldg. 33, Rm. F320, Greenbelt, MD 21071, [mest@kasei.gsfc.nasa.gov](mailto:mest@kasei.gsfc.nasa.gov).

**Introduction:** The martian southern highlands contain impact craters that display pristine to degraded morphologies, and preserve a record of degradation that can be attributed to fluvial, eolian, mass wasting, volcanic and impact-related processes. However, the relative degree of modification by these processes and the amounts of material contributed to crater interiors are not well constrained.

Impact craters ( $D > 10$  km) within Terra Cimmeria ( $0^{\circ}$ - $60^{\circ}$ S,  $190^{\circ}$ - $240^{\circ}$ W), Terra Tyrrhena ( $0^{\circ}$ - $30^{\circ}$ S,  $260^{\circ}$ - $310^{\circ}$ W) and Noachis Terra ( $20^{\circ}$ - $50^{\circ}$ S,  $310^{\circ}$ - $340^{\circ}$ W) are being examined to better understand the degradational history and evolution of highland terrains. The following scientific objectives will be accomplished. 1) Determine the geologic processes that modified impact craters (and surrounding highland terrains). 2) Determine the sources (e.g. fluvial, lacustrine, eolian, mass wasting, volcanic, impact melt) and relative amounts of material composing crater interior deposits. 3) Document the relationships between impact crater degradation and highland fluvial systems. 4) Determine the spatial and temporal relationships between degradational processes on local and regional scales. And 5) develop models of impact crater (and highland) degradation that can be applied to these and other areas of the martian highlands. The results of this study will be used to constrain the geologic, hydrologic and climatic evolution of Mars and identify environments in which subsurface water might be present or evidence for biologic activity might be preserved.

**Methodology:** This research utilizes multiple data sets to accomplish the objectives stated above. Images (Viking Orbiter, MOC, and THEMIS vis and IR (day)) are being analyzed to characterize (a) the preservation states (e.g., "fresh", "degraded", "moderately degraded", "highly degraded", and "buried" or "exhumed" [1-3]) and (b) interior deposits of craters. MOLA data and the IDL module GRIDVIEW [4] are being used to estimate morphometric parameters for craters (e.g., diameter, depth, slopes), regional and local slopes, and thicknesses and volumes of crater interior deposits. THEMIS infrared images and TES data are being used to characterize surface properties (e.g., emission, roughness) of crater interior deposits, and the Mars Observer GRS is being used to observe the distribution of surficial hydrogen. These data sets

will be used to produce detailed geologic and geomorphic maps of individual impact craters, especially those containing enigmatic deposits, as well as maps at local and regional scales. Individual craters, such as Terby, Rabe, Proctor, Schaeberle, Schroeter, Martz, Gale and several unnamed craters, that are well-covered Mars data, will be mapped in detail. Mapping could determine if similar degradation styles were common, such as by precipitation-driven processes or by a regional mantling unit [5,6] that contributes material to crater floors via mass wasting, or differ from crater to crater, suggesting mostly localized processes were (are) active. Relative age relationships for crater interior deposits will be determined by calculating crater size-frequency distribution statistics.

**Observations:** Extensive evidence that fluvial, mass wasting, eolian, volcanic and impact-related processes were involved in degradation, infilling and subsequent erosion of impact craters are preserved in the highlands of Noachis Terra, Tyrrhena Terra and Terra Cimmeria.

Fluvial systems dissect large parts of these highland terrains; their tributaries erode crater rim and ejecta materials and breach the rims of some craters. The interior walls of many craters are incised with gullies. Some gullies head at or near crater rims, suggesting erosion by precipitation-derived runoff [1,7-10], whereas other gullies originate at discrete layers along crater walls [11]. Some craters contain small valley networks along their rims, which resulted in emplacement of alluvial fans [12,13] on their floors. The presence of these features suggests fluvial processes were a key factor in crater degradation.

Many highland craters contain lobate debris aprons (Late Hesperian to Amazonian) that extend onto their floors, suggesting volatile-driven mass wasting also actively modified crater interiors and contributed significant amounts of material to crater floors. Mass wasting may have been an equally important process of crater degradation, especially in the highlands northeast and east of Hellas basin [14-18] where volatiles appear to have been abundant, and less important in other areas where volatiles may have been spatially or temporally less abundant [7-9,10].

Dune fields and dark splotches within craters, such as Rabe and Proctor [19], indicate eolian processes may contribute, or at least redistribute, significant quantities of sediments to interior deposits [7-10].

Many craters could also contain materials deposited within lacustrine or playa environments. Morphologic evidence - inflow and outlet valleys, layered deposits, deltas, sedimentary terraces, and shorelines - suggests some martian craters may have contained lakes [9,10,20-25].

Several craters, such as Millochou [9], Terby [26-28], Schaeberle, Schroeter and several large unnamed craters [9,29,30], contain enigmatic interior deposits relative to nearby craters of similar size or age. Some deposits are layered and form plateaus that stand hundreds of meters above surrounding floor materials or in some cases are topographically higher than the crater's rim, such as Gale [31]. Many craters also contain pits, suggesting collapse of volatile-rich material, and (or) they contain deposits that display surfaces that have been modified more significantly than nearby craters of similar size and age.

Several impact craters north and west of Hellas basin contain surface materials that display similar surface textures. One deposit in particular, 'rugged material' mapped in Millochou [9], displays a 'stucco-like' surface texture, is typically found along the outer edges of the crater interior and generally slopes down from the crater wall toward its center. The characteristics of this unit, combined with the fact that it is usually found in craters with gullied interior walls, suggest it may consist of heavily degraded fluvial deposits and (or) mass wasted materials. Similarly, the surfaces of many plateaus and massifs that compose enigmatic crater deposits are generally similar in appearance to the 'pitted material' observed in Millochou [9].

**Discussion:** Many highland impact craters exhibit evidence that they were modified (eroded and infilled) to various degrees by multiple geologic processes. The morphologies of most craters and the deposits preserved on their floors suggest significant quantities of volatiles were involved, either atmospherically-derived and (or) released from the subsurface. However, the nature of the processes varies spatially and temporally across relatively short distances (100's of kilometers) of the highlands. For example, Promethei Terra (east of Hellas basin) displays large relatively young debris aprons, small Hesperian-aged valley networks, and large outflow systems [14-18], whereas adjacent Tyrrhena Terra (north of Hellas basin) is dissected by extensive Noachian-aged valley networks, contains enigmatic crater interior deposits, and lacks debris aprons [9,10]. In addition, craters that contain similar features (pits, plateaus, etc.) and (or) deposits similar in appearance suggest either emplacement of similar materials (and sequences of

materials) and (or) the processes of emplacement and subsequent modification were widespread. It is the ongoing goal of this research to use all available Mars data to identify deposits associated with specific source areas and determine the process(es) of their erosion and emplacement, quantify crater interior deposits (i.e., thickness, volume), and correlate crater degradation processes locally and regionally to spatially and temporally constrain volatile distribution as well as assess climate change on Mars.

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